Conservation Assessment of *Hibbertia puberula* subsp. *extensa* R.T.Mill (Dilleniaceae)

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Hibbertia puberula subsp. *extensa* R.T.Mill (Dilleniaceae)

Distribution: Endemic to NSW
Current EPBC Act Status: Not listed
Current NSW BC Act Status: Listed at the species level as Endangered
Proposed listing on NSW BC Act: Critically Endangered

Reason for change: *Hibbertia puberula* has been listed as Endangered under the BC Act, however the three subspecies that occur within NSW are now being assessed separately as each is considered to have a different conservation status.

Summary of Conservation Assessment

Hibbertia puberula subsp. *extensa* R.T.Mill was found to be eligible for listing as Critically Endangered under IUCN Criteria B1ab(i,ii,iii,iv,v); C2a(i).

The reasons for the species being eligible for listing in the Critically Endangered category are that: 1) the species has a very highly restricted geographic range with a minimum extent of occurrence estimated at 66 km^2; 2) it has a low total number of mature individuals (estimated at ≤175); 3) the population is considered to be severely fragmented; and 4) there is an observed continuing decline in the area, extent and quality of habitat and inferred continuing decline in the extent of occurrence, area of occupancy, number of subpopulations, and number of mature individuals due the clearing, fragmentation, and degradation of habitat, and adverse fire regimes, particularly high frequency fire and high severity fire.

Hibbertia puberula subsp. *extensa* in Dharawal National Park, NSW. Image: Rob Miller.

Description and Taxonomy

Hibbertia puberula subsp. *extensa* R.T.Mill is a subspecies in the family Dilleniaceae. The species *Hibbertia puberula* is described as a decumbent to suberect shrublet "with few wiry branches to 30 cm long, pubescent, often glabrescent, with simple long and short hairs (hairs often curved or hooked). Leaves with petiole 0.2–0.5 mm long; lamina narrowly ovate to almost linear, (1.2–)3–5.5(-8) mm long, (0.6–) 0.8–1.4(–1.8) mm wide; base appearing abruptly constricted because margin strongly revolute (under surface not visible); apex more or less obtuse. Flowers single or rarely up to 3-flowered; pedicels short; bracts more or less elliptic, mostly 3–3.5(–4) mm long, leaf-like. Calyx with outer lobes ovate, more or less beaked with margin recurved distally, mostly 6–10 mm long, outer surface hispid, inner surface pubescent to silky hairy; inner calyx lobes oblong-elliptic to oblong-ovate, mostly 5–7 mm long, hispid with spreading bristles mainly along central ridge. Petals obovate, 6–8 mm long, broadly bilobed. Stamens (9–)10–14, inserted on one side of ovary, subequal; filaments fused on lower one-third. Carpels 2, slightly hairy, sometimes almost villous. Fruit puberulous with simple hairs." (Toelken and Miller 2012; PlantNet 2023a).

The subspecies *Hibbertia puberula* subsp. *extensa* is further described as "branches stiff-woody and lateral ones spreading up to about right angles. Leaf lamina mainly lanceolate. Outer calyx lobes ovate, 6.1–7.9 mm long, 3.1–3.8 mm wide, acute to beaked with ± strongly recurved margins and distinctly raised ridge towards the apex, strigose to hirsute; inner calyx lobes elliptic rarely oblong-ovate, 4–5 mm long, 2.9–3.4 mm wide, with innermost two abruptly constricted into minute terminal point continuous with broad membranous margins, hirsute to strigose with hairs becoming smaller towards the margins. Stamens 4–7; anthers 0.8–1.2 mm long." (Toelken and Miller 2012; PlantNet 2023b).

Hibbertia puberula subsp. *extensa* is distinguished from *H. puberula* subsp. *puberula* and *H. puberula* subsp. *glabrescens* by having fewer than or equal to seven stamens and having lateral branches usually spreading almost at right angles to the main axis (*cf*. stamens 9–18; irregularly and untidily branched in subsp. *puberula* and subsp. *glabrescens*) (Toelken and Miller 2012).

Hibbertia puberula can be distinguished from other similar species, such as those in the *H. sericea* complex, by "the combination of its linear-lanceolate leaves with a central vein raised up to the leaf apex, only simple hairs, absence of a tuft of hairs between the stamens and the petals, puberulous ovary, and obloid seeds" (Toelken 2000). *Hibbertia puberula* had previously been included in *H. simulans* but is distinguished from that species by its puberulous ovary, wiry branches, and decumbent habit (Toelken 2000).

Distribution and Abundance

Hibbertia puberula subsp. *extensa* is currently known to be endemic to the Sydney Basin Bioregion of New South Wales (NSW) (SEWPaC 2012). The subspecies has a disjunct distribution comprised of multiple small sites and subpopulations, where it is often highly localised. The distribution extends from South Maroota and Bateau Bay in the north to Wanganderry Tablelands and Appin in the south. The distribution of *H. puberula* subsp. *extensa* spans the traditional lands of the Dharug, Tharawal, Gundungurra, Eora, and Kuring-gai peoples (AIATIS 1996).

Hibbertia puberula subsp. *extensa* occurs across 8–10 known subpopulations as defined by IUCN (2024; Table 1). This range accounts for the taxonomic uncertainty of the Bateau Bay subpopulation and the probable loss of the South Maroota subpopulation. A record collected from around Mellong in 2021 was initially identified as *H. puberula* subsp. *extensa* (RBGDT 2023). However, further surveys at the locality undertaken in 2023 found these records to not be *H. puberula* subsp. *extensa*, and possibly representative of an undescribed taxon (Miller *et al.* 2024). Consequently, the Mellong records have been excluded from this assessment.

Table 1. Population breakdown of *Hibbertia puberula* subsp. *extensa.* All sites and subpopulations surveyed in 2023 with the exception of the South Maroota subpopulation. Subpopulations listed north to south.

Subpopulation	Tenure	Estimated number of mature individuals	Date of last fire	Notes	References
Bateau Bay	Crown land	15	1991	Some taxonomic uncertainty remains around this subpopulation.	A. Orme *in litt*. 23 May 2024; DCS 2024a, 2024c; Miller *et al.* 2024; NPWS 2024
South Maroota	Crown land	0	?	Not surveyed in 2023 as the last time the site was visited it had been bulldozed. The subspecies had only been found at this locale and thus is inferred to have been lost.	R. Miller *in litt.* June 2024
Sarahs Knob	NPWS	≤29	2002 (all); 2016 (partial		DCS 2024a, 2024b; Miller *et al.* 2024; NPWS 2024
Dharawal	NPWS / freehold	46	2002 (all); 2017 (partial		DCS 2024a, 2024b; Miller *et al.* 2024; NPWS 2024
Wedderburn North	Crown land or LALC land	25	2002		DCS 2024a; Miller *et al.* 2024; NPWS 2024; R. Miller pers. comm. June 2024
Wedderburn South	Crown land or LALC land	1	2002		DCS 2024a; Miller *et al.* 2024; NPWS 2024; R. Miller pers. comm. June 2024
Appin West	Council or freehold	≤50	2015	The exact number of mature individuals is unknown, but it is estimated that the total is unlikely to exceed 50 based on recent survey data.	Price *et al.* 2016; DCS 2024a, 2024b; Miller *et al.* 2024

Subpopulation	Tenure	Estimated number of mature individuals	Date of last fire	Notes	References
Appin East	Council or freehold	2	2015	Comprised of two sites. Plants were unable to be relocated at one site.	DCS 2024a, 2024b; Miller *et al.* 2024; NPWS 2024
Cataract Dam	Council or freehold	5	2015		DCS 2024a, 2024b; Miller *et al.* 2024; NPWS 2024
Wanganderry	NPWS	?	2020	Surveys in 2023 failed to relocate the subspecies. It is possible the 2019–2020 fires have led to the loss of this subpopulation.	DCS 2024a, 2024b; Miller *et al.* 2024; NPWS 2024
Population total		**≤173**			

Subpopulations are identified by a distance of ≥1 km between occurrences, as gene flow from either pollination or seed dispersal is considered to be very limited beyond this distance. Native bees (Tucker and Bernhardt 2000) and pollen-consuming beetles (Keighery 1975) are considered the most effective pollinators of zygomorphic *Hibbertia* species, which have stamens inserted on only one side of the carpels. Most solitary and stingless bee species which have been studied to date forage less than or up to ~1 km (Greenleaf *et al.* 2007; Zurbuchen *et al*. 2010). As the specific bee and beetle pollinators of *H. puberula* subsp. *extensa* are unknown, generic native bee pollination distances are used to estimate the maximum gene flow distance between subpopulations, with a maximum effective pollination distance of 1 km used to determine subpopulations.

Subpopulations

The Appin West and Appin East subpopulations occur in bushland on Crown land south of Appin Road, Appin. The Appin West subpopulation is the largest subpopulation of *Hibbertia puberula* subsp. *extensa*. It is comprised of four sites in upland swamp associated underlying sandstone and sandstone outcrops (Miller *et al.* 2024). The Appin East subpopulation is comprised of two sites approximately 1.4 km southeast of the Appin West subpopulation. Both sites occur in upland swamp, one of which is confined to a narrow band of exposed sandstone outcropping at the downslope edge of a swamp (Miller *et al.* 2024). All sites within both subpopulations occur partially or fully in mapped Coastal Upland Swamp in the Sydney Basin Bioregion, a threatened ecological community (TEC) (NSW DCCEEW 2024a).

The Cataract Dam subpopulation occurs on Crown land to the north of Cataract Dam, and approximately 1.3 km south-southwest of the Appin West subpopulation. The Cataract Dam subpopulation occurs at the ecotone of upland swamp and eucalypt woodland (Miller *et al.* 2024), in mapped Coastal Upland Swamp in the Sydney Basin Bioregion (NSW DCCEEW 2024a).

The Wedderburn North and Wedderburn South subpopulations both occur in bushland to the west of Wedderburn Aerodrome, where they are separated by approximately 1.1 km. These subpopulations occur on Crown land or Local Aboriginal Land Council (LALC) land (R. Miller pers. comm. June 2024). The Wedderburn north subpopulation

is comprised of four sites which occur around intermittent seepages in heath and woodland with one site occurring along the verges of a track (Miller *et al.* 2024). The Wedderburn South subpopulation occurs as a single site in heathy upland swamp.

The Dharawal subpopulation is located within and adjacent to Dharawal National Park (NP) and is comprised of three sites along the verges of a fire trail and in surrounding vegetation (Miller *et al.* 2024). Two sites occur within the boundaries of the national park and one site occurs on private property. Habitat includes slashed vegetation along the edge of a fire trail, seepages associated with sandstone outcroppings, and exposed sandstone rock plate (Miller *et al.* 2024).

The Sarahs Knob subpopulation occurs within Heathcote NP. This subpopulation is comprised of a single spread-out site along the edge of a maintenance track with plants preferring intermittent seepage zones associated with skeletal soils and exposed rock plates (Miller *et al.* 2024).

The Wanganderry Tablelands subpopulation is known from one very small area of habitat growing within rock plate heath (Miller *et al.* 2024). Targeted searches in 2023 failed to relocate this subpopulation and it is unknown whether the subspecies persists at this location (Miller *et al.* 2024).

The South Maroota subpopulation was known from a small flat area of skeletal soil over rockplate in South Maroota (R. Miller *in litt.* June 2024). The area was not resurveyed in 2023 as the last time it was visited it had been bulldozed and was being utilised as a turning circle for firefighting vehicles (R. Miller *in litt.* June 2024). As the subspecies was only known from this one small area, it is possible that the subpopulation has been lost.

The Bateau Bay subpopulation occurs on a parcel of Crown land surrounded by residential developments, with habitat highly localised along a short section of a water infrastructure access track on the ecotone of two woodland communities (Miller *et al.* 2024). The taxonomic identity of this subpopulation remains uncertain (A. Orme *in litt.* 23 May 2024; Miller *et al.* 2024) and is provisionally included in this assessment as *Hibbertia puberula* subsp. *extensa*.

Extent of occurrence and area of occupancy

The extent of occurrence (EOO) was calculated at 66–4,391 km^2 due to uncertainty of outlying records and is based on a minimum convex polygon enclosing all mapped occurrences of the species, the method of assessment recommended by IUCN (2024). The area of occupancy (AOO) is estimated to be 20–32 km^2 and was calculated using 2 x 2 km grid cells, the scale recommended by IUCN (2024). A plausible range for both AOO and EOO is provided due to the taxonomic uncertainty of the Bateau Bay records, and uncertainty around whether the subspecies persists in the Wanganderry Tablelands and South Maroota. Both EOO and AOO were calculated using ArcGIS (Esri 2015), enclosing all known records from recent survey data, reports, and expert communications (M. Saunders pers. obs. November 2023; Miller *et al.* 2024; R. Miller *in litt.* June 2024).

Population size and trends

The estimated minimum population size of *Hibbertia puberula* subsp. *extensa* is ≤200 mature individuals, with fewer than 250 individuals across all age classes counted during surveys undertaken to inform this assessment (Miller *et al*. 2024).

During targeted surveys undertaken in 2023, most plants at the two largest sites (Appin Site 4a and 4b) within the Appin West subpopulation had signs of dieback, with woody bare main stems and dead side shoots present (Miller *et al.* 2024). As Appin site 4a was newly discovered, it was not possible to make inferences on the population trend at this location; however, Appin site 4b had been surveyed twice previously (Miller *et al.* 2024). Most individuals showed significant signs of dieback and only a few had reproductive structures, contrasting with the healthy, large specimens observed in 2020 and 2021, which may suggest that these individuals are senescing (Miller *et al.* 2024).

Flower mites have been documented to be adversely affecting individuals in the Appin West and Wedderburn North subpopulations (Miller *et al.* 2024). Flower mites cause deformity to the flower buds and typically result in galls which prevent seed production, further reducing the reproductive capacity of affected individuals (Miller *et al.* 2024).

Although there are no long monitoring data or information on long-term population trends available for this subspecies, the surveys undertaken in 2023 failed to relocate numerous previously recorded individuals, suggesting these may have died, with a range of plausible threats proposed as causative factors (Miller *et al.* 2024).

Ecology

Habitat

Hibbertia puberula subsp. *extensa* typically occurs in heathy upland swamps along intermittent seeps associated with underlying sandstone or sandstone rockplate (Toelken and Miller 2012; Miller *et al.* 2024). These upland swamps are frequently highly localised, and the species' very specific habitat preferences result in small and discrete areas of occurrence. The subspecies occurs on shallow sandy soils which may be humic, loamy, or lateritic (Miller *et al.* 2024). Soil landscapes on which *H. puberula* subsp. *extensa* has been recorded include Hawkesbury and Lucas Heights in its distribution south and west of Sydney, and Norah Head at Bateau Bay (SALIS 2024).

Hibbertia puberula subsp. *extensa* occurs at elevations ranging from 30 m above sea level (a.s.l.) at Bateau Bay, 200–370 m a.s.l. around Appin and Dharawal NP, and 730 m a.s.l. on the Wanganderry Tablelands. Across its range, average annual rainfall ranges from 786 mm at High Range (the closest weather station to the Wanganderry Tablelands subpopulation) (BOM 2024a) to 1,243 mm at Wyong (the closest weather station to the Bateau Bay subpopulation) (BOM 2024b), while mean temperatures range from 11.4–25.4°C in High Range (BOM 2024c) to 17.8–30.1°C in Campbelltown (the closest weather station to the Appin area subpopulations) (BOM 2024d).

Commonly co-occurring species include *Eucalyptus racemosa, E. sieberi*, *Corymbia gummifera*, *Banksia ericifolia*, *B. oblongifolia*, *Leptospermum squarrosum*, *Melaleuca thymifolia*, *Dillwynia floribunda*, *Epacris microphylla*, *Hibbertia ericifolia* subsp. *acutifolia, Xanthorrhoea resinosa*, and *Drosera spathulata* (Miller *et al.* 2024). Co-occurring threatened species listed on the *Biodiversity Conservation Act 2016* include *Grevillea raybrownii* and *Grevillea parviflora* (Miller *et al.* 2024).

Hibbertia puberula subsp. *extensa* may occur in the following mapped Plant Community Types (PCTs): Woronora Plateau Scribbly Gum Woodland (PCT 3598), Sydney Hinterland Enriched Sandstone Bloodwood Forest (PCT 3619), Sydney Coastal Upland Swamp Heath (PCT 3924), Sydney Hinterland Apple-Blackbutt Gully

Forest (PCT 3615), and Southern Sydney Scribbly Gum Woodland (PCT 3590) (NSW DCCEEW 2020). This list is not exhaustive, and it is likely that the subspecies occurs in other PCTs in NSW.

Hibbertia puberula subsp*. extensa* has been recorded in one TEC in the Sydney Basin Bioregion: Coastal Upland Swamp in the Sydney Basin Bioregion (NSW DCCEEW 2024a).

Fire and disturbance ecology

Little is known about the fire and disturbance ecology of *Hibbertia puberula* subsp. *extensa*. The genus contains both resprouting species and obligate seeding species (Ferrer-Paris *et al*. 2022). *Hibbertia puberula* subsp. *puberula* has been documented to resprout following fire (G. Phillips pers. comm. December 2023). However, Miller *et al.* (2024) noted that *H. puberula* subsp. *extensa* was killed by fire at the type locality in Appin and suggested that the subspecies may be an obligate seeder.

Reproductive and seed ecology

Hibbertia puberula subsp. *extensa* generally flowers from October to December and March to April (Toelken and Miller 2012). Seed set and release in the sister taxon *H. puberula* subsp. *glabrescens* has been documented to occur during the summer, typically within a month or so of flowering (Cuneo *et al.* 2018).

Hibbertia are insect-pollinated (entomophilous), with a range of insects including native bees (Apidae, Colletidae, and Halictidae), pollen-eating flies (Syrphidae), beetles (Coleoptera), and European Honeybees (*Apis mellifera*), considered pollinators of *Hibbertia* flowers (Keighery 1975; Armstrong 1979; Tucker and Bernhardt 2000). However, there is debate over the primary vectors of *Hibbertia* pollen. Keighery (1975) found beetles to be the primary vectors of pollen of the zygomorphic *H. hypericoides*, while Tucker and Bernhardt (2000) considered native bees to be the most effective pollinators of zygomorphic *Hibbertia* species. As *H. puberula* subsp. *extensa* is zygomorphic, native bees and/or beetles are likely to be the primary pollinators.

Hibbertia puberula subsp. *extensa* seeds possess a fleshy aril (Toelken and Miller 2012), a structure that has been demonstrated to aid dispersal by ants (myrmecochory) in other *Hibbertia* species (Berg 1975). While ants have been documented transporting seeds of other species up to 77 m in sclerophyllous vegetation in the Southern Hemisphere, dispersal distances are typically <2 m (Gómez *et al*. 1998). As such, it is unlikely that seeds of *H. puberula* subsp. *extensa* are transported far from parent plants. *Hibbertia puberula* is known to have a persistent seedbank (Cuneo *et al.* 2018).

The specific germination cues of *Hibbertia puberula* subsp. *extensa* are unknown. *Hibbertia* seeds are known to be dormant at the time of release, although the type of dormancy varies from species to species, with both physiological dormancy (PD) and morphophysiological dormancy (MPD) recorded (Schatral *et al.* 1997; Allan *et al*. 2004; Hidayati *et al*. 2012). Seeds with PD are water-permeable but have a physiological inhibiting mechanism which prevents radicle emergence (Baskin and Baskin 2014) and require specific environmental triggers to promote germination (Penfield 2017). Seeds with MPD have a PD coupled with a rudimentary embryo which must grow to a critical size within the seed prior to germination (Baskin and Baskin 2014). Smoke or karrikinolide (KAR_1; a compound found in smoke) has been shown

to aid germination in several *Hibbertia* species (Dalziell *et al.* 2004; Hidayati *et al.* 2012; Wulff *et al.* 2012). In a study of four sympatric *Hibbertia* species in Western Australia, Hidayati *et al.* (2012) found that seasonal changes in temperature and moisture were important factors influencing germination, while photo-regime affected one species, and smoke triggered germination in two species. Similarly, warm stratified seeds of *H. glaberrima* experienced higher germination rates than non-stratified seeds, with germination further increased by exposure to KAR_1 (Dalziell *et al.* 2004). Based on these studies, the environmental conditions required to enable *H. puberula* subsp. *extensa* to germinate probably include seasonal changes (*e.g.*, changes in temperature and rainfall) and possibly the development of a rudimentary embryo. Given that the subspecies occurs in fire-prone environments, smoke may also provide a physiological cue for germination.

Lifespan and generation length

The primary juvenile period of *Hibbertia puberula* subsp*. extensa* is unknown. The subspecies appears to be slow growing, with most seedlings at one site recorded eight years post-fire inferred to be juveniles (Miller *et al.* 2024). This is suggestive of a primary juvenile period of at least 7–8 years.

The lifespan of *Hibbertia puberula* subsp*. extensa* is not known. However, the closely related *H. sericea* is estimated to have a lifespan of 20–50 years (Falster *et al.* 2021), and this estimate is used for *H. puberula* subsp*. extensa* due to it belonging to the *H. sericea* group.

The generation length of *Hibbertia puberula* subsp*. extensa*, which is likely to rely on a combination of resprouting and seedling recruitment after disturbance, can be estimated using the age of first reproduction + *z* * length of reproductive period, where *z* is a number between 0 and 1 calculated on the relationship between survivorship and the relative fecundity of young versus old individuals in the population (IUCN 2024). Using a maximum lifespan of 20–50 years, a primary juvenile period of 7–8 years, and a value for *z* of 0.21 as calculated for other plant species with similar lifespans (Fung and Waples 2017), the generation length of *H. puberula* subsp*. extensa* is estimated at approximately 10.5–16 years.

Cultural significance

It is unknown whether *Hibbertia puberula* subsp. *extensa* has cultural significance to Aboriginal peoples. There is at least one species in the genus with recorded use. The Yaegl Aboriginal community in northern NSW used the leaves of *H. scandens* medicinally to treat sores and rashes (Packer *et al*. 2012).

This assessment is not intended to be comprehensive of the traditional ecological knowledge that exists for *Hibbertia puberula* subsp. *extensa*, or to speak for Aboriginal people. Aboriginal people have a long history of biocultural knowledge, which comes from observing and being on Country, and evolves as it is tested, validated, and passed through generations (Woodward *et al*. 2020). Aboriginal peoples have cared for Country for tens of thousands of years (Bowler *et al*. 2003; Clarkson *et al*. 2017). There is traditional ecological knowledge for all plants, animals and fungi connected within the kinship system (Woodward *et al*. 2020). Traditional ecological knowledge referenced in this assessment belongs to the relevant knowledge custodian and has been referenced in line with the principles of the NSW Indigenous Cultural and Intellectual Property protocol (ICIP) (Janke and Company 2023).

Threats

Hibbertia puberula subsp. *extensa* is threatened by the clearing, fragmentation, and degradation of habitat, particularly from recreational vehicle use, bike use, and track maintenance, and adverse fire regimes, particularly high frequency and high severity fire. Weed invasion and coal mining are potential threats at several sites. Flower mites are affecting the reproductive capacity of plants in at least two subpopulations and may be an emerging threat.

Clearing, fragmentation, and degradation of habitat

The clearing, fragmentation, and degradation of habitat is considered a serious threat to *Hibbertia puberula* subsp. *extensa* (Miller *et al.* 2024). Except for the Wanganderry Tablelands subpopulation, all subpopulations of *H. puberula subsp. extensa* are threatened by some form of habitat clearance or degradation. Eight of the 8–10 subpopulations are fully or partially on non-reserved lands, defined here as freehold land, Crown land, and Council land. Three subpopulations occur fully or partially on NPWS estate; however, there is substantial evidence of habitat degradation occurring at two of these subpopulations due to track maintenance and widening, track establishment, and recreational vehicle use. As the subspecies is frequently found in highly localised upland swamps where it occurs in very specific habitat niches, it is particularly vulnerable to habitat loss and degradation.

Habitat clearance due to track maintenance and widening

Since the first observation of *Hibbertia puberula* subsp. *extensa* at site 1 in the Appin West subpopulation, the fire trail has been upgraded, resulting in the loss of habitat for the subspecies (Miller *et al.* 2024). In the Wedderburn North subpopulation, individuals at three sites (2a–2c) are located so close to the edge of a 4WD track (and in some cases directly on the track) that any future track maintenance or upgrades have the potential to eliminate these sites entirely (Miller *et al.* 2024). Similarly, most of the Dharawal subpopulation exists within the remaining roadside verge of a fire trail in Dharawal NP. Recent upgrade works have removed skeletal soil habitat along the trail verge, which has likely resulted in the loss of mature individuals and the seedbank from these areas (Miller *et al.* 2024) and corresponding population decline. Furthermore, two of the three sites which comprise this subpopulation are confined to the maintenance zone adjacent to the track, which is subject to trittering and grading, likely resulting in sustained degradation of habitat and threatening plants with mortality from machinery (Miller *et al.* 2024). The alignment of a maintenance track in Heathcote NP is likely to have resulted in the permanent loss of mature individuals in the Sarahs Knob subpopulation, as the road passes directly through prime habitat of the subspecies and has replaced it with bitumen and gravel (Miller *et al.* 2024). The known extent of the South Maroota subpopulation is thought to have been destroyed due to track widening. The last time this subpopulation was visited, the only known locale where the subspecies had been documented had been bulldozed and was being utilised as a turning circle for firefighting vehicles (R. Miller *in litt.* June 2024).

Habitat clearance from powerline maintenance, dumping of spoil from construction, and sediment deposition from erosion have been documented in the Sarahs Knob subpopulation (Miller *et al.* 2024).

Altered hydrology due to track establishment and erosion

The excavation or erosion of fire trails to the bedrock is altering the local hydrology of the Appin West, Wedderburn, and Dharawal subpopulations, by diverting subsurface flows along the trails themselves (Miller *et al.* 2024). Similarly, the construction of a maintenance track in Heathcote NP has affected the Sarahs Knob subpopulation by altering local hydrology via the construction of dish drains which redirect subsurface flows to a single discharge point (Miller *et al.* 2024).

The establishment of informal tracks is similarly altering local hydrology at some sites. Deep rutting by 4WDs and trail bikes has resulted in both the fragmentation of habitat and altered hydrology of the swamps in the Appin subpopulations, causing habitat to dry out by dewatering adjacent habitat (Miller *et al.* 2024). The single known individual comprising the Wedderburn South subpopulation is located between three motorbike ruts along a dirt track (Miller *et al.* 2024). The excavation of this track has altered local hydrology and is funnelling water away from the location of the individual (Miller *et al.* 2024).

Altered flows have the potential to cause localised drying of *Hibbertia puberula* subsp. *extensa* habitat, which may in turn reduce the suitability of habitat or prevent successful recruitment. The lowering of the water table may also facilitate the encroachment of large, woody shrubs, such as *Banksia ericifolia*, which have the capacity to outcompete *H. puberula* subsp. *extensa* (Miller *et al.* 2024).

Habitat degradation from recreational vehicle use and the establishment of informal or illegal tracks

Recreational vehicle use and the associated establishment of informal or illegal tracks is a serious and growing threat to the Appin West, Appin East, Wedderburn North, Wedderburn South, and Cataract Dam subpopulations. Many of the sites in the Appin subpopulations are subject to uncontrolled access by 4WDs, trail bikes, and mountain bikes which are causing erosion and direct damage to habitat (Miller *et al.* 2024). The threat of inappropriate recreational vehicle use in the Appin area has grown significantly over the past several years and is likely to continue due to increased development in the surrounding suburbs (Miller *et al.* 2024). Arson of vehicles and the dumping of waste have been documented proximate to sites in the Wedderburn North subpopulation (Miller *et al.* 2024).

The location of the Bateau Bay subpopulation along and immediately adjacent to a water infrastructure access track predisposes it to habitat degradation from frequent use, with individuals on the track edge at risk of being trampled (Miller *et al.* 2024).

'Clearing of native vegetation' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Land clearance' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

<u>Adverse fire regimes</u>

Little is known about the fire ecology of *Hibbertia puberula* subsp. *extensa* but there is evidence that the subspecies is vulnerable to adverse fire regimes, particularly high frequency and high severity fire. Fire has been documented to kill *H. puberula* subsp. *extensa*, with all previously documented individuals at one site in the Appin West subpopulation apparently killed by a prescribed burn in 2015 (Miller *et al.* 2024). In contrast, the sister taxon *H. puberula* subsp. *puberula*, has been documented to resprout following fire (G. Phillips pers. comm. December 2023). While further

sampling is needed to understand the range of variation in fire responses within and between subspecies, recruitment and seed bank accumulation in both obligate seeders and resprouters can be susceptible to high fire frequency, while resprouters may experience high rates of mortality when exposed to high severity fire (e.g. Nicholson *et al.* 2017).

The failure to relocate the Wanganderry Tablelands subpopulation might indicate the loss of the subspecies from the locality due to the 2019–2020 wildfire (Miller *et al.* 2024). The location of this subpopulation is mapped within an area that experienced extreme fire severity, defined as full canopy consumption (NSW DCCEEW 2024b), suggesting that any individuals present might have been killed by the fire. When the subspecies was first recorded at this locality, it was noted to be near or on exposed sandstone outcroppings in skeletal soils (Miller *et al.* 2024). Post-fire erosion of exposed soils is a significant problem, with sediment yields increasing by up to several orders of magnitude (Benavides-Solorio and MacDonald 2005; Larsen *et al.* 2009). Given the susceptibility of skeletal soils to post-fire erosion coupled with frequent observations of eroded skeletal soils in the area during the 2023 surveys, it is possible that any soil seedbank which survived the 2019–2020 fire has been washed into unsuitable areas for *Hibbertia puberula* subsp. *extensa* (Miller *et al.* 2024). If this has occurred, it is possible this subpopulation has been lost, although further surveys are required to confirm this.

High frequency fire is also likely to a threat to *Hibbertia puberula* subsp. *extensa*. As the subspecies is thought to have a long primary juvenile period of up to 7–8 years (Miller *et al.* 2024), recurrent fires even within somewhat longer timeframes than this have the potential to greatly diminish or rapidly eliminate subpopulations. Repeated short interval fires can also lead to depressed or failed resprouting in resprouting species (*e.g.*, Enright *et al*. 2011; Karavani *et al.* 2018; Fairman *et al.* 2019).

Climate change projections indicate a future trend of increased fire weather and more frequent fires in southeast Australia (Dowdy *et al*. 2019; Jones *et al*. 2022). The Sydney and Central Coast regions are projected to become hotter, have fewer cold nights under 2°C, have more hot days over 35°C, and have a longer fire season by 2079 (BOM and CSIRO 2022; AdaptNSW 2024). Regionally, it is projected with high confidence that climate change will result in a harsher fire-weather climate in the future (CSIRO 2024). It is plausible that these changes will lead to more frequent, intense, and severe fires, and changes in fire season, which will in turn adversely affect the *Hibbertia puberula* subsp. *extensa* population in the future.

'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Fire regimes that cause declines in biodiversity' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

<u>Reduced habitat suitability via altered hydrology due to climate change</u>

Altered hydrology due to climate change is likely to result in reduced habitat suitability to *Hibbertia puberula* subsp. *extensa*. Coastal upland swamps in the Sydney Basin Bioregion are projected to undergo declines of at least 30% and up to 97% in both area and suitability from 1990–2070 (Keith *et al.* 2014). Long-term monitoring has

found a trend of increasing *Banksia* thicket at the expense of Restioid heath (Mason and Keith 2016). Competition from the expansion of *Banksia* and other shrubs has been identified as a threat to *H. puberula* subsp. *extensa* (Miller *et al*. 2024).

'Anthropogenic Climate Change' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*. 'Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Weed invasion

Weed invasion is a potential threat at several sites in the Appin West, Dharawal, and Sarahs Knob subpopulations. Several invasive grasses have been documented to be increasing proximate to confirmed *Hibbertia puberula* subsp. *extensa* habitat, including *Eragrostis curvula* (African love grass), *Andropogon virginicus* (whiskey grass), and *Axonopus fissifolius* (narrow-leaved carpet grass) (Miller *et al.* 2024). The erosion of trails has been shown to lead to sediment deposition after rain, which predisposes these areas to weed invasion (Miller *et al.* 2024). Dumping of spoil from track maintenance works also poses a risk of transporting weed seeds around *H. puberula* subsp. *extensa* habitat (Miller *et al.* 2024).

'Invasion of native plant communities by exotic perennial grasses' is listed as a Key Threatening Processes under the *Biodiversity Conservation Act 2016*. 'Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants' is listed as a Key Threatening Process under the *Environment Protection and Biodiversity Conservation Act 1999*.

Longwall coal mining

It is possible that longwall coal mining operations near to the Appin West and Wedderburn North subpopulations has altered local hydrology (Miller *et al.* 2024). Subsidence and cracking of bedrock have occurred near the Wedderburn North subpopulation, and two collieries are located near to the Appin West subpopulation (Miller *et al.* 2024). It is unknown whether the *Hibbertia puberula* subsp. *extensa* proximate to these operations have suffered any adverse effects as a result of mining activities, however there is now strong evidence of impacts on upland swamp habitats (Mason *et al*. 2021; Krogh *et al*. 2022; Keith *et al*. 2023).

'Alteration of habitat following subsidence due to longwall mining' is listed as a Key Threatening Process under the *Biodiversity Conservation Act 2016*.

Reduced reproductive capacity due to flower mite infestations

Flower mites have been noted to be adversely affecting plants in the Appin West and Wedderburn North subpopulations (Miller *et al.* 2024). The identity of these mites is unknown and therefore it is unknown whether the species is native or exotic. It is also unknown whether the degree to which the mites are affecting plants is normal or being exacerbated by other threats, *e.g*., altered hydrology reducing the ability of plants to produce defensive compounds. Affected plants have reduced reproductive capacity, as flowers with mite infestations typically do not set seed (Miller *et al.* 2024). In some cases, affected plants had all buds showing signs of mite infestation (Miller *et al.* 2024), suggesting recruitment failure is likely to occur with these individuals. It is possible mites have been a contributing factor to the apparent senescence of plants in the Appin West subpopulation, although this would need to be investigated.

Severe fragmentation and number of locations

Hibbertia puberula subsp. *extensa* is considered to be severely fragmented as >50% of its population occurs in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance relative to dispersal kernel of the species, as per the IUCN (2024) definition.

This assessment has defined subpopulations by dispersal distance of pollinators; however, severe fragmentation considers the dispersal distance of the diaspore (*i.e.*, potential to recolonise), as per the IUCN (2024). Therefore, for the purposes of assessing whether *Hibbertia puberula* subsp. *extensa* is severely fragmented, habitat patches defined by probable seed dispersal distances are used. Seeds of the subspecies possess a fleshy aril (Toelken and Miller 2012), a structure that has been demonstrated to aid dispersal by ants in other *Hibbertia* species (Berg 1975), and ants typically disperse seeds of other species <2 m to tens of metres in sclerophyllous vegetation in the Southern Hemisphere (Gómez *et al*. 1998. The IUCN (2024) states "distances several times greater than the (long-term) average dispersal distance of the taxon may be considered isolated".

To meet the definition of *severely fragmented*, the IUCN (2024) states that "more than half of the individuals (or, more than half of the occupied habitat area) must be in small and isolated patches", where "small" refers to a number below that required to support a viable population. The IUCN (2024) states that the condition of severely fragmented can be met by either more than half the individuals or *more than half of the occupied habitat area* being in small and isolated patches. Many habitat patches are small (many supporting <10 individuals and as few as one) and isolated (by roads, expanses of urban or agricultural lands, fine-scale topographic features, or by distances in the order of hundreds of metres to kilometres). Furthermore, many of these habitat patches are concentrated along edges of contiguous areas of bushland, which may limit their viability as a consequence of higher risk of human disturbance (*e.g.*, earthworks, dumping, off-road vehicles, and fires) and restricted options for dispersal to/from other suitable habitat. Given the subspecies' limited dispersal ability, once an isolated habitat patch becomes locally extinct, the probability of recolonisation is low. Furthermore, subspecies' highly specific microhabitat requirements reduces the likelihood of the availability of suitable habitat between habitat patches and therefore limits the potential for recolonisation. Consequently, many of the small and isolated habitat patches are unlikely to viable in the long-term. This is evidenced by the presumed loss of the South Maroota subpopulation to track widening activities. Track widening and inappropriate recreational vehicle use continues to threaten the persistence of numerous habitat patches around Wedderburn, Dharawal, and Appin.

Hibbertia puberula subsp. *extensa* occurs at 3–4 threat-defined locations, as per the IUCN (2024) definition, due to the most serious plausible threat resulting in the lowest number of locations for the subspecies being adverse fire regimes, particularly high frequency fire and high severity fire. The Wanganderry Tablelands and Bateau Bay subpopulation each occur in individual locations. The remaining subpopulations all occur in 1–2 threat-defined locations, as it is plausible that a future fire could occur at a scale which affects most or all of the individuals present amongst these subpopulations.

Assessment against IUCN Red List criteria

For this assessment it is considered that the survey of *Hibbertia puberula* subsp. *extensa* has been adequate and there is sufficient scientific evidence to support the listing outcome.

Criterion A *Population size reduction*

A. Population size reduction. Population reduction (measured over the longer of 10 years or 3 generations) based on any of A1 to A4

	Critically Endangered	Endangered	Vulnerable
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1 Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased.

A2 Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

A3 Population reduction projected, inferred or suspected to be met in the future (up to a maximum of 100 years) *[(a) cannot be used for A3]*.

A4 An observed, estimated, inferred, projected or suspected population reduction where the time period must include both the past and the future (up to a max. of 100 years in future), and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible.

based on any of the following:

(a) direct observation *[except A3]*

(b) an index of abundance appropriate to the taxon

(c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality

(d) actual or potential levels of exploitation

(e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

Outcome

Hibbertia puberula subsp. *extensa* is Data Deficient under Criterion A.

Population reductions

There are insufficient data to estimate, infer or project the magnitude of past or future reductions in the population size of *Hibbertia puberula* subsp. *extensa*.

Conclusion

Hibbertia puberula subsp. *extensa* is Data Deficient under Criterion A as there are insufficient data to estimate, infer or project the magnitude of past or future reductions in its population size.

Criterion B *Geographic range*

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following 3 conditions:			
(a) Severely fragmented OR Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline observed, estimated, inferred or projected in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			

Outcome

Hibbertia puberula subsp. *extensa* is Critically Endangered under B1ab(i,ii,iii,iv,v).

EOO and AOO

Hibbertia puberula subsp. *extensa* has a highly to very highly restricted geographic distribution with an extent of occurrence (EOO) calculated at 66–4,391 km^2. The lower

end of the range is meeting the threshold of <100 km^2 for Critically Endangered and the upper end of the range is meeting the threshold of <5,000 km^2 for Endangered. The area of occupancy (AOO) is calculated to be 20–32 km^2, meeting the threshold of <500 km^2 for Endangered. The range of both EOO and AOO considers the inferred loss of the South Maroota subpopulation due to habitat clearing, the possible loss of the Wanganderry Tablelands subpopulation due to the 2019–2020 wildfire, and the taxonomic uncertainty of the Bateau Bay records, with the low end of the range excluding all three subpopulations and the high end of the range including all three subpopulations. Given the uncertainty around these three subpopulations, and the recommendation by the IUCN (2024) that a precautionary approach is to be taken when dealing with uncertainty, the low end of the range is considered most appropriate for determining extinction risk of the subspecies under this Criterion. Therefore, the EOO is considered to be 66 km^2, meeting threshold for Critically Endangered.

Number of threat-defined locations

Hibbertia puberula subsp*. puberula* occurs at 3–4 threat-defined locations, as per the IUCN definition (IUCN 2024).

Severely fragmented

The population of *Hibbertia puberula* subsp. *puberula* is inferred to be severely fragmented, as it is thought that >50% of its population occurs in habitat patches that are (1) smaller than would be required to support a viable population, and (2) separated from other habitat patches by a large distance relative to dispersal kernel of the species, as per the IUCN (2024) definition.

Continuing decline

The combined threats of the clearing, fragmentation, and degradation of habitat, and adverse fire regimes, particularly high frequency and high severity fire, are observed to be causing continuing decline in the area, extent and quality of habitat and inferred to be causing continuing decline in the number of mature individuals.

Targeted surveys undertaken in 2023 to inform this assessment surveyed all known habitat of the subspecies, except for the South Maroota subpopulation, which was inferred to have been destroyed from road widening. These surveys revealed an observed continuing decline in the area, extent, and quality of habitat due to the clearing, fragmentation, and degradation of habitat, caused primarily by track maintenance and associated activities, and inappropriate recreational vehicle and bike use in habitat areas. The presumed loss of the South Maroota subpopulation to habitat clearing is inferred to have resulted in continuing decline in the extent of occurrence, area of occurrence, and number of subpopulations of the subspecies.

Adverse fire regimes are inferred to be contributing to continuing decline in the number of mature individuals. It is inferred that the 2019–2020 wildfire killed all individuals in the Wanganderry Tablelands subpopulation. It is plausible that the Wanganderry subpopulation also lost its soil seedbank due to post-fire erosion of the highly susceptible skeletal soils where the subspecies was found (Miller *et al.* 2024). If this has occurred, the subpopulation may now be extinct, which would result in a loss of EOO, AOO, number of subpopulations, and number of locations. However, further surveys would need to be undertaken to provide conclusive evidence as to whether this has occurred.

Extreme fluctuations

There is no evidence to suggest *Hibbertia puberula* subsp. *extensa* undergoes extreme fluctuations.

Conclusion

Hibbertia puberula subsp. *puberula* is eligible to be listed as Critically Endangered under Criterion B as it has a very highly restricted geographic distribution (a minimum EOO of 66 km^2), is inferred to be severely fragmented, and is undergoing continuing decline in the extent of occurrence, area of occupancy, area, extent, and quality of habitat, number of subpopulations, and number of mature individuals.

Criterion C Small population size and decline

C. Small population size and decline		Critically Endangered	Endangered	Vulnerable
Number of mature individuals		< 250	< 2,500	< 10,000
AND at least one of C1 or C2				
C1. An observed, estimated or projected continuing decline of at least (up to a max. of 100 years in future):		25% in 3 years or 1 generation (whichever is longer)	20% in 5 years or 2 generations (whichever is longer)	10% in 10 years or 3 generations (whichever is longer)
C2. An observed, estimated, projected or inferred continuing decline AND at least 1 of the following 3 conditions:				
(a)	(i) Number of mature individuals in each subpopulation	≤ 50	≤ 250	≤ 1,000
	(ii) % of mature individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals				

Outcome

Hibbertia puberula subsp. *extensa* is Data Deficient under Criterion C1 and Critically Endangered under Criterion C2a(i).

Number of mature individuals

Hibbertia puberula subsp. *extensa* has an estimated minimum population size of ≤200 mature individuals, meeting the threshold of <250 for Critically Endangered.

Continuing decline

Continuing decline in the number of mature individuals is inferred due to the clearing, fragmentation, and degradation of habitat, and adverse fire regimes, particularly high frequency fire and high severity fire, but there are insufficient data to quantify the magnitude of such declines across the required timescales.

Mature individuals in each subpopulation

The number of mature individuals in each subpopulation is estimated to be ≤50, meeting the threshold for Critically Endangered.

% of mature individuals in a single subpopulation

The largest subpopulation of *Hibbertia puberula* subsp. *extensa* is estimated to support ~29% of the known population.

Extreme fluctuations

There is no evidence to suggest *Hibbertia puberula* subsp. *extensa* undergoes extreme fluctuations.

Conclusion

Hibbertia puberula subsp. *extensa* is Data Deficient under Criterion C1 but eligible to listed as Critically Endangered under Criterion C2a(i) as it has an estimated population size of ≤200 mature individuals, each subpopulation consists of <50 mature individuals, and there is an inferred continuing decline in the number of mature individuals due to the clearing, fragmentation, and degradation of habitat, and adverse fire regimes, particularly high frequency fire and high severity fire.

Criterion D Very small or restricted population

D. Very small or restricted population			
	Critically Endangered	Endangered	Vulnerable
D. Number of mature individuals	< 50	< 250	D1. < 1,000
D2. *Only applies to the VU category* Restricted area of occupancy or number of locations with a plausible future threat that could drive the taxon to CR or EX in a very short time.	-	-	D2. typically: AOO < 20 km^2 or number of locations ≤ 5

Outcome

Hibbertia puberula subsp. *extensa* is eligible to be listed as Endangered under Criterion D and Vulnerable under Criterion D2.

Number of mature individuals

Hibbertia puberula subsp. *extensa* has an estimated minimum population size of ≤200 mature individuals, below the threshold of <250 for Endangered.

Risk of future extinction in a very short amount of time (D2)

Hibbertia puberula subsp. *extensa* has an area of occupancy of 20–32 km^2, occurs in four threat-defined locations, and is vulnerable to stochastic events due to being severely fragmented, as per the IUCN (2024) definition, which may drive the species to extinction in a very short time.

Criterion E Quantitative Analysis

E. Quantitative Analysis			
	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations, whichever is longer (100 years max.)	≥ 20% in 20 years or 5 generations, whichever is longer (100 years max.)	≥ 10% in 100 years

Outcome

Hibbertia puberula subsp. *extensa* is considered Data Deficient under Criterion E.

Probability of extinction

No quantitative analysis has been undertaken to assess the extinction probability of this subspecies and there are currently insufficient data to undertake one.

Conservation and Management Actions

Hibbertia puberula is currently listed on the NSW *Biodiversity Conservation Act 2016* and a conservation project has been developed by the NSW Department of Climate Change, Energy, the Environment and Water. The conservation project identifies priority locations, critical threats and required management actions to ensure the species is extant in the wild in 100 years. *Hibbertia puberula* sits within the Site-managed species management stream of the SoS program and the conservation project can be viewed here: https://savingourspecies.environment.nsw.gov.au/project/28.

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APPENDIX 1

Assessment against *Biodiversity Conservation Regulation 2017* criteria
The Clauses used for assessment are listed below for reference.

Overall Assessment Outcome:

Hibbertia puberula subsp*. extensa* was found to be Critically Endangered under Clauses 4.3(a)(d)(e i,ii,iii,iv) and 4.4(a)(e i,ii A(I)).

Clause 4.2 – Reduction in population size of species
(Equivalent to IUCN criterion A)
Assessment Outcome: Data Deficient.

(1) - The species has undergone or is likely to undergo within a time frame appropriate to the life cycle and habitat characteristics of the taxon:			
	(a)	for critically endangered species	a very large reduction in population size, or
	(b)	for endangered species	a large reduction in population size, or
	(c)	for vulnerable species	a moderate reduction in population size.
(2) - The determination of that criteria is to be based on any of the following:			
	(a)	direct observation,	
	(b)	an index of abundance appropriate to the taxon,	
	(c)	a decline in the geographic distribution or habitat quality,	
	(d)	the actual or potential levels of exploitation of the species,	
	(e)	the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.	

Clause 4.3 - Restricted geographic distribution of species and other conditions
(Equivalent to IUCN criterion B)
Assessment Outcome: Critically Endangered under Clause 4.3(a)(d)(e i,ii,iii,iv).

The geographic distribution of the species is:						
	(a)	for critically endangered species				very highly restricted, or
	(b)	for endangered species				highly restricted, or
	(c)	for vulnerable species				moderately restricted,
and at least 2 of the following 3 conditions apply:						
	(d)	the population or habitat of the species is severely fragmented or nearly all the mature individuals of the species occur within a small number of locations,				
	(e)	there is a projected or continuing decline in any of the following:				
		(i)	an index of abundance appropriate to the taxon,			
		(ii)	the geographic distribution of the species,			
		(iii)	habitat area, extent or quality,			
		(iv)	the number of locations in which the species occurs or of populations of the species,			
	(f)	extreme fluctuations occur in any of the following:				
		(i)	an index of abundance appropriate to the taxon,			
		(ii)	the geographic distribution of the species,			
		(iii)	the number of locations in which the species occur or of populations of the species.			

Clause 4.4 - Low numbers of mature individuals of species and other conditions
(Equivalent to IUCN criterion C)
Assessment Outcome: Critically Endangered under Clause 4.4(a)(e i,ii A(I)).

The estimated total number of mature individuals of the species is:						
	(a)	for critically endangered species				very low, or
	(b)	for endangered species				low, or
	(c)	for vulnerable species				moderately low,
and either of the following 2 conditions apply:						
	(d)	a continuing decline in the number of mature individuals that is (according to an index of abundance appropriate to the species):				
		(i)	for critically endangered species			very large, or
		(ii)	for endangered species			large, or
		(iii)	for vulnerable species			moderate,
	(e)	both of the following apply:				
		(i)	a continuing decline in the number of mature individuals (according to an index of abundance appropriate to the species), and			
		(ii)	at least one of the following applies:			
			(A)	the number of individuals in each population of the species is:		
				(I)	for critically endangered species	extremely low, or
				(II)	for endangered species	very low, or
				(III)	for vulnerable species	low,

			(B)	all or nearly all mature individuals of the species occur within one population,
			(C)	extreme fluctuations occur in an index of abundance appropriate to the species.

Clause 4.5 - Low total numbers of mature individuals of species
(Equivalent to IUCN criterion D)
Assessment Outcome: Endangered under Clause 4.5(b).

The total number of mature individuals of the species is:			
	(a)	for critically endangered species	extremely low, or
	(b)	for endangered species	very low, or
	(c)	for vulnerable species	low.

Clause 4.6 - Quantitative analysis of extinction probability
(Equivalent to IUCN criterion E)
Assessment Outcome: Data deficient.

The probability of extinction of the species is estimated to be:			
	(a)	for critically endangered species	extremely high, or
	(b)	for endangered species	very high, or
	(c)	for vulnerable species	high.

Clause 4.7 - Very highly restricted geographic distribution of species– vulnerable species
(Equivalent to IUCN criterion D2)
Assessment Outcome: Vulnerable under Clause 4.7.

For vulnerable species,	the geographic distribution of the species or the number of locations of the species is very highly restricted such that the species is prone to the effects of human activities or stochastic events within a very short time period.